THE OCCURRENCE, ORIGIN AND VEGETATION OF LOWLAND PEAT IN MALAYA

B. R. Hewitt
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[Read 29th March, 1967]

Synopsis

The extent, origin, distribution and vegetation of the lowland peat of Malaya are described. Some reference is made to similar peat formations in adjacent areas in south-east Asia and factors responsible for the development of peat are discussed.

Introduction

Peat swamps cover extensive areas of the humid tropics and occur in the three main rain forest regions of the world; in south-east Asia, tropical America, and tropical Africa. Richards (1952) has summarized some of the available information on the vegetation and nature of peat swamps. In the humid tropics of south-east Asia, on the landward side of the mangrove or beach forests, peat forests are encountered in many areas extending along the coastal plains. They cover almost one fifth of the area of Sumatra and occur along the coasts of the Malayan Peninsula, Borneo and southern New Guinea. Next to the sub-arctic peat formations of the northern hemisphere, particularly in the U.S.S.R., these tropical peats probably belong to the largest ever described. Lowland peat is of great importance in south-east Asia because of its occurrence in areas where rice can be grown. Due to the physical conditions, high acidity, low fertility and often toxic concentrations of some elements it is very difficult to grow padi on peatland. There are approximately 2 million acres of peat on the Malayan Peninsula and 40 million acres in Indonesia.

The study of tropical peat began in Indonesia, the first publications appearing in 1854. Bernelot Moens (1865) described a kind of peat he found in Java and noted the resemblances between coal and peat formation. In 1870, Edeling gave a description of the Bidara Tjina swamp and mentioned floating islands in the swamp. Stoop in 1886 described the Rawa Pening near Ambarawah in Java in which a floating island formed. This phenomenon had already been described by Junghuhn in 1854. Potonie and Koorders in 1909 published their findings after crossing Sumatra and commented that the formation of tropical peat was an example of coal formation. Up to this time it was generally accepted in scientific circles that peat soil can originate only under a temperate or cold climate. Nevertheless, Schimper in 1908 stated that in the tropics "zur Torfbildung auszer im Gebirge über 1200 m. nirgends kommt". After 1909, the study of tropical peat attracted greater attention and the number of publications increased.

Lang in 1914 described the accumulation of peat and the presence of black water rivers in Sumatra and Malacca. Keilhacks (1915) described peats in the mountains and on the lowlands of Ceylon. In the same year Gates (1915) mentioned a small swamp containing peat in the mountains of the Philippines.

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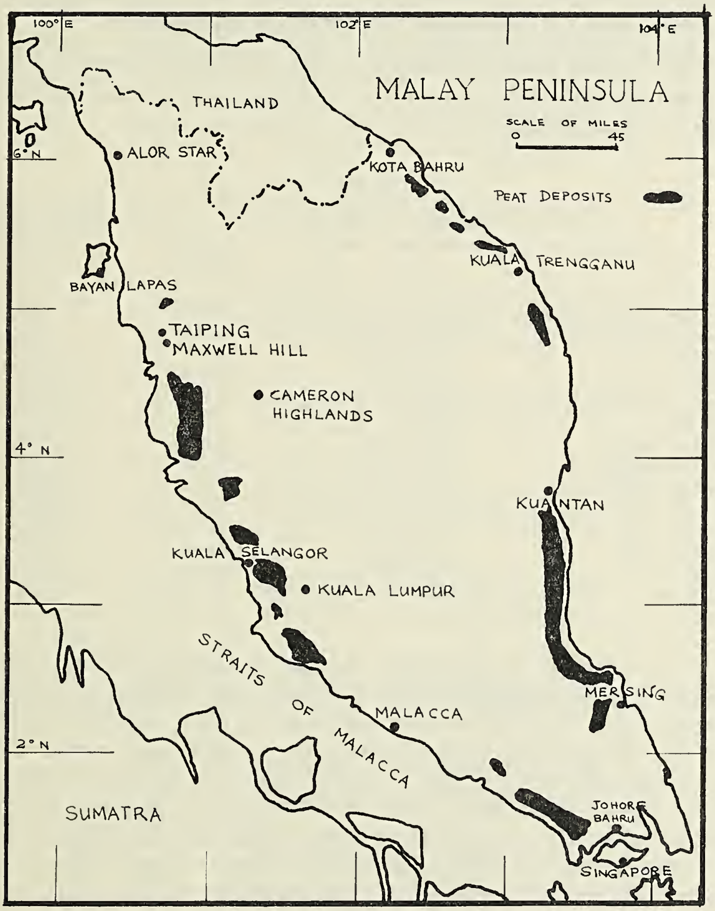
Tropical peat in Africa was described by Krenkel in 1920. He mentioned Cyperaceae-Gramineae moors in the mountains and forest swamps in the lowlands. It would appear from his description that these bogs in Africa are similar to those in south-east Asia. He commented "Die Feuchtigkeit ist für die Bildung eines Moores in allen Klimaten ausschlaggebend. Die Temperatur steht ihr als weniger wichtig nach, wenn sie auch nicht unter ein Mindest hinabreichen darf". This conclusion is quite important and is true for peat formation in all climates. The forest peat swamps on the east coast of Sumatra were described by van Heurn (1923) and Mohr (1922) and those of Palembang



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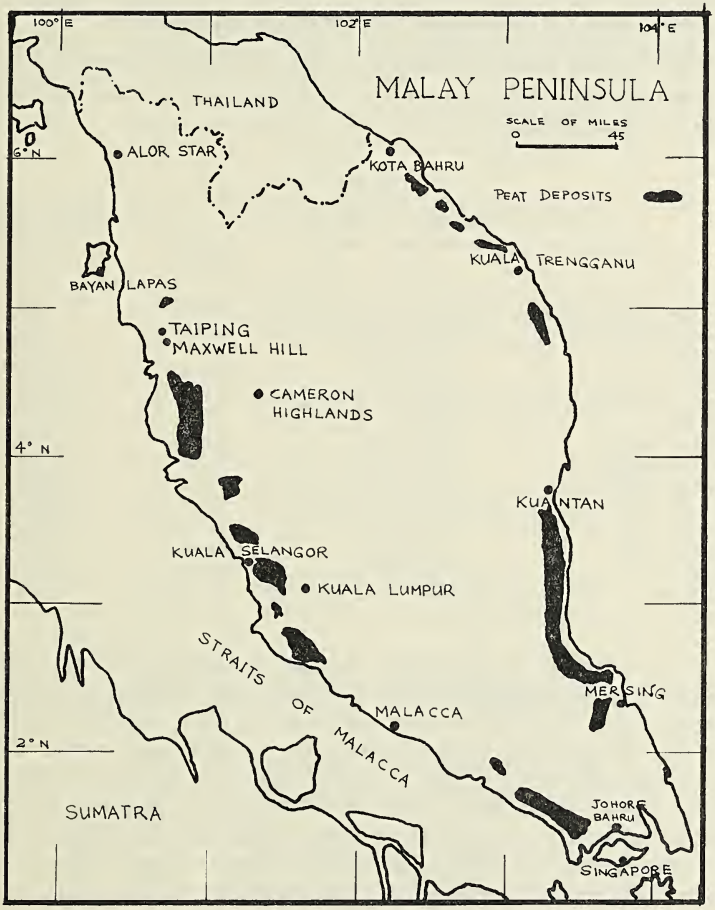

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Climate

The climate of the Malayan Peninsula has been described as a Hot Equatorial Climate of the monsoonal sub-type (Miller, 1931). This classification is primarily based on temperature and secondarily on rainfall. It is, however, difficult to explain by generalization the rainfall regime of the lowland stations where the distribution depends on position and exposure in relation to the two monsoon currents. The temperature regime is dependent on altitude and is quite different in the lowlands and the highlands.

However, rainfall in Malaya is one of the most important criteria in establishing both divisions between the seasons and any seasonal variations. There are four seasons delineated by the two monsoons:

1. The north-east monsoon commencing in October and ending in March.
2. The south-west monsoon which commences at the end of May and ends in September.

Table 1

Station	Mean annual temperature range °F.	Range °F.	Height above sea-level (ft.)
Kota Baharu . .	72·6–89·8	17·2	15
Kuala Trengganu . .	72·4–89·0	16·6	105
Kuantan	71·2–90·0	18·8	62
Mersing	73·1–88·0	14·9	149
Johore Baharu . .	72·8–89·1	16·3	50
Malacca	73·1–86·3	12·8	22
Kuala Lumpur . .	72·1–90·8	18·7	111
Kuala Selangor . .	73·1–89·4	16·3	40
Cameron Highlands	57·3–73·4	15·9	4,750
Maxwell Hill . .	63·4–76·4	13·0	3,400
Taiping	71·7–91·2	19·5	59
Bayan Lepas . .	73·6–88·1	14·5	11
Baling	71·2–89·5	18·3	170
Alor Setar	71·3–88·7	17·4	15

The other two seasons correspond to the inter-monsoonal periods which vary according to the location of the station. The north-east monsoon therefore brings a heavy rainfall to the east coast from October to March while the south-west monsoon is mainly effective on the west coast from May to September. Generally, the rains occur as thunderstorms of short duration during which heavy rain falls, and the absence of general rain over large areas tends to make the incidence of those falls unpredictable. The climatic factors of temperature, rainfall, humidity, sunshine and radiation are dealt with for some selected stations which are marked on the map.

Temperature

Atmospheric temperatures are very uniform with little diurnal or seasonal variation. There are, however, marked differences between stations. These are dependant on altitude. For example, at Johore Baharu at a height of 50 feet (15·2 m.) above sea level the mean annual temperature range is from 72·8° F. to 89·1° F. (22·7° C. to 31·7° C.) whereas at Cameron Highlands at a height of 4,750 feet (1,447·8 m.) the range is 57·3° F. to 73·4° F. (14·1° C. to 23·0° C.). There is therefore a fall in temperature of 0·324° F. for every 100 feet (0·6° C. per 100 m.) increase in altitude (see Table 1).

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Table 2
Average rainfall (in inches)

Station	Average number wet days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
East Coast														
Kota Baharu	179	9·16	5·31	5·68	4·33	5·44	6·18	5·69	6·50	8·43	10·22	23·19	23·34	113·47
Kuala Trengganu	184	5·85	6·69	6·72	5·88	4·46	4·30	3·97	5·63	8·09	11·68	23·14	21·38	107·89
Kuantan	180	15·16	7·47	8·89	6·58	6·62	5·33	5·25	5·72	8·21	9·66	14·93	23·19	117·01
Mersing	198	14·60	7·83	7·42	5·34	5·81	5·21	6·03	6·34	6·31	8·19	12·84	20·54	106·46
Johore Baharu	200	12·82	8·70	10·06	7·56	8·55	6·23	6·36	9·03	7·49	8·63	11·32	13·17	109·92
West Coast														
Malacca	162	4·91	4·04	6·39	5·87	6·72	7·91	7·68	8·65	7·97	10·01	8·34	6·05	84·54
Kuala Lumpur*	204	5·90	5·60	9·32	10·80	7·75	5·56	4·11	5·90	7·69	10·86	10·48	8·50	92·47
Kuala Selangor	134	7·30	4·29	5·21	6·53	5·13	3·70	3·51	4·44	5·83	9·05	9·39	8·68	73·06
Cameron Highlands†	239	6·29	5·04	8·60	12·32	9·59	5·57	5·09	6·90	10·15	13·30	13·20	9·43	105·48
Maxwell Hill†	216	11·17	8·76	14·41	20·64	19·28	13·85	11·21	15·69	19·33	25·90	22·30	15·15	197·69
Bayan Lepas	172	3·80	4·41	6·00	9·71	11·57	6·37	8·82	9·83	15·44	16·37	10·18	4·12	106·62
Taiping*	223	13·59	11·90	17·16	19·70	13·29	7·03	6·87	9·37	12·49	20·59	18·73	15·04	165·76
Baling*	151	3·50	3·80	6·09	10·39	8·73	5·69	6·02	6·95	9·65	14·16	11·00	5·81	91·79
Alor Setar	181	2·22	2·02	5·72	8·73	10·23	7·35	8·04	10·28	11·85	12·45	8·42	4·41	91·72

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the stations is a hot equatorial type of a monsoon variety. He classifies sub-tropical climate as having all months above 43° F. (6·1° C.) and with no cold season. On the basis of temperature alone the hill areas from about the 3,833 feet (1,000 m.) contour level upwards would be classified as sub-tropical. However, such areas are probably better classified as a hot tropical monsoon hill climate.

The rainfall data for these stations are given below (Table 2) and include the mean monthly rainfalls, average annual rainfall and the average number of wet days per year (that is, at least 0·09 inches (0·25 mm.) per day). The east coast receives rain maxima from October to January. The rainfall pattern on the west coast is not as consistent and position and topography are very important, while nearness of the island of Sumatra has great influence. The effect of the south-west monsoon is clearly seen at Alor Setar, the most northerly west coast station out of the main influence of the island of Sumatra.

TABLE 3

Average relative humidity (%)

Station	June		December	
	6 a.m.	1 p.m.	6 a.m.	1 p.m.
Kota Baharu . .	93	68	93	76
Kuala Trengganu . .	95·9	71·9	94·4	80·4
Kuantan	98·4	65·6	97·3	81·0
Mersing	95·4	76·4	93·1	81·6
Johore Baharu. . . .	—	69·0	—	70·7
Malacca	97·9	74·4	95·9	68·8
Kuala Lumpur . .	94·7	60·8	97·7	64·0
Kuala Selangor . .	—	65·5	—	68·4
Cameron Highlands . .	—	98·7	—	98·3
Maxwell Hill	—	60·1	—	63·4
Bayan Lepas	94·3	69·3	89	63·5
Taiping	—	63·8	—	68·7
Baling	—	60·6	—	59·4
Alor Setar	94	67	94	60

At this station most rain is received during the months April to November. Taiping receives a high rainfall which is inconsisent for the lowland stations. This is perhaps due to its close proximity to the elevated area of Maxwell Hill. On comparing the rainfall of Indonesia (Mohr and van Baren, 1959) with that of the Malayan Peninsula it is evident that there is greater variation in Indonesia. According to Mohr and van Baren's (1959) modification of Köppens (1916) classification all stations in Malaya are continuously wet or moist since the rainfall never falls below 2·4 inches (60 mm.) except at one station, Alor Setar on the west coast where the average monthly rainfalls for January and February are 2·2 inches and 2·0 inches (56 and 51 mm.). However, these monthly averages are so little below 2·4 inches that they can be regarded as forming a very weak dry season.

Humidity

The highest relative humidity occurs at 6 a.m. simultaneously with the minimum daily temperature, and the lowest relative humidity usually occurs at the same time as the maximum daily temperature at 1 p.m. (Table 3).

Sunshine

Sunshine is nowhere constant and, in fact, the number of sunshine hours at the stations on the Malayan Peninsula are less than at many places in more temperate climates. The following data (Table 4) show the amount of the stations is a hot equatorial type of a monsoon variety. He classifies sub-tropical climate as having all months above 43° F. (6·1° C.) and with no cold season. On the basis of temperature alone the hill areas from about the 3,833 feet (1,000 m.) contour level upwards would be classified as sub-tropical. However, such areas are probably better classified as a hot tropical monsoon hill climate.

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TABLE 4
Hours of sunshine

Station	Yearly percentage of total possible	Mean daily sunshine (hours)	Highest daily mean for one month	
Kota Baharu	57	6·97	10·09	March
Kuala Trengganu	57	6·90	10·16	March
Kuantan	49	5·88	8·34	Feb.
Mersing	50	6·11	7·99	March
Johore Baharu (Singapore) ..	45	5·40	7·16	March
Malacca	49	6·01	7·32	May
Kuala Lumpur	53	6·35	7·45	March
Ipoh	55	6·65	7·82	March
Bayan Lepas	56	6·78	8·29	March
Aor Setar..	61	7·31	9·02	March

Radiation

It is often thought that the total radiation at the tropics is greater than elsewhere. However, often, the radiation in temperate latitudes is greater than in the tropics due to absorption by the water vapour in the humid air of the tropics. The figures in Table 5 (Landsberg, Lippman and Paffen, 1965) illustrate this point.

TABLE 5
Radiation

Area	Radiation in K cal/cm$_2$/Year
Malay Peninsula	140–160
Most of Australia	160–200
Southern Africa	160–200
Southern U.S.A.	160–200

OCCURRENCE AND ORIGIN OF LOWLAND PEAT

The Malayan Peninsula extends 700 miles from the Isthmus of Kra in the north to Singapore in the south and has a total area of approximately 51,000 square miles. In general, it consists of a central backbone of mainly granite mountain ranges running north and south. The Kerbau Coulisse constitutes the main range which includes individual peaks over 7,000 feet in height (Scrivenor, 1931). Skirting the central ranges are the coastal alluvial plains which are about 40 miles wide on the western side and 20 miles wide on the eastern side. The lowland peat occurs on the coastal plain near and parallel to the coast (see map).

The topographic units of lowland Malaya are readily distinguished by their relief features, drainage pattern and manner of distribution. Topography is the most consistent and most important feature associated with the occurrence of peat swamps and is closely related to the Recent geological history of the area. The coastal plain is probably a relic of the Sunda peneplanation which was submerged after the Pleistocene glaciation and later filled in by deposits from the older central mountain ranges of the Peninsula (Molengraaf, 1922). The Recent changes in sea level have influenced the topography so that a number of topographical units have been formed which are conducive to the formation of lowland peat.

sunshine recorded as a percentage of the total maximum possible, together with the mean daily sunshine hours and the daily average for the sunniest month.

TABLE 4

Hours of sunshine

Station	Yearly percentage of total possible	Mean daily sunshine (hours)	Highest daily mean for one month	
Kota Baharu	57	6·97	10·09	March
Kuala Trengganu	57	6·90	10·16	March
Kuantan	49	5·88	8·34	Feb.
Mersing	50	6·11	7·99	March
Johore Baharu (Singapore) ..	45	5·40	7·16	March
Malacca	49	6·01	7·32	May
Kuala Lumpur	53	6·35	7·45	March
Ipoh	55	6·65	7·82	March
Bayan Lepas	56	6·78	8·29	March
Aor Setar..	61	7·31	9·02	March

Radiation

It is often thought that the total radiation at the tropics is greater than elsewhere. However, often, the radiation in temperate latitudes is greater than in the tropics due to absorption by the water vapour in the humid air of the tropics. The figures in Table 5 (Landsberg, Lippman and Paffen, 1965) illustrate this point.

TABLE 5

Radiation

Area	Radiation in K cal/cm$_2$/Year
Malay Peninsula	140–160
Most of Australia	160–200
Southern Africa	160–200
Southern U.S.A.	160–200

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Below the central ranges on the Malayan Peninsula are the remnants of a terrace which are covered with poor heath forest with an excessively drained soil composed of white quartz sands and silts. The formation of the terrace corresponds to several stages in the lowering of the sea level during the Quaternary. The terrace remnants are elongated parallel to the former coastline and mostly lie approximately 200 feet above sea level, although the height given for lowland Sarawak is between 25 feet and 100 feet (Wall, 1964).

Other lowland soil-topographic units include the riverine soils and vegetation, the estuarine unit and the beaches. The riverine unit is characterized by flat topography and poorly drained gley soils. The estuarine unit consists of estuaries, deltas, lagoons, abandoned meanders and coastal flats which are still subject to occasional or periodic tidal incursions and have halomorphic soils carrying mangrove and nipah vegetation. The beaches carry a characteristic vegetation and soil and vary in width from a few feet to more than a mile. The soils are podsolized and carry grasses and shrubs on old strand lines together with *Casuarina equisetifolia* on the most recent beach which is usually about 4 ft. above high tide level.

With the exception of terrace remnants peat swamps occur in association with all these topographic units. They occur when barriers known as permatong impede drainage. The permatong may arise as a result of change in river courses, floods depositing heavy alluvium along part of the river or building a dyke preventing tidal incursions but mainly they have been formed because of Recent changes in sea level resulting in the presence of beach ridges at varying heights up to about 50 feet above sea level (Nassin, 1964), and orientated parallel to the present coastline. Behind each of these barriers peat swamps may develop. Within the peat swamp itself a mixture of organic and mineral soils may occur due to the type of under lying sediment, deposition of silt by floods and the depth of the peat present. So that the peat swamp contains peat itself, which has an ash content less than 35%, together with muck soils and organic clays with ash content between 35% and 65%, which grade into mineral soils.

Stages in the formation of peat swamp can be summarized as:

Stage 1.—Deposits of alluvium in bays, deltas or sheltered embayments along the coast are colonized by mangrove. With continued deposition further offshore accentuated by Recent changes in sea level the more inland mangrove is progressively replaced by transitional communities and a shallow peat overlying mangrove clays is formed.

Stage 2.—With the continued deposition of alluvium on the seaward perimeter the swamps advance replacing mangrove. Therefore as the distance from the sea of the original swamp increases rivers tend to back up and begin depositing alluvium along their banks, which consequently are raised above the level of the original swamp subsoils so that the characteristic saucer-shaped foundations of the peat evolve. Peat accumulation then proceeds rapidly and a shallow lenticular structure develops.

Stage 3.—The rate of peat accumulation in the swamp centre falls and a typical flattened bog plain develops, usually occupied by a characteristic vegetation community.

There is little differentiation in a peat profile. However, a typical description is:

0–3 inches. A black amorphous material with a granular structure, and containing some wood fragments.

3–12 inches. The colour changed from black to dark coffee brown colour.

12–36 inches. Reddish brown fibrous material.

36–72 inches. Reddish brown material.

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Vegetation

The peat carries a type of tropical rainforest which is characteristically heterogenous in regard to species but contains less variety of species than the normal lowland rain forest on dry land (Wyatt–Smith, 1959). This is due to the special conditions required for growth and support in a soft, acid and anaerobic medium, so that only those species specifically adapted can survive. Therefore many trees have stilts and aerial roots. The main species present are: Gonystylaceae, *Gonystylus bancanus*; Guttifereae, *Calophyllum retusum, C. scriblitifolium, Cratoxylon arborescens*; Theaceae, *Tetramerista glabra*; Myristicaceae, *Myristica lowiana*; Dipterocarpaceae, *Anicoptera marginata, Shorea rugosa var. uliginosa, S. teysmanniana, S. platycarpa*; Euphorbiaceae, *Blumeodendron tokbrai*; Linaceae, *Ctenolophon parvifolius*; Leguminosae, *Dialium patens, Koompassia malaccensis*; Bombacaceae, *Durio carinatus, Neesia altissima*; Myrtaceae, *Eugenia* spp.; Sapotaceae, *Ganua motleyana, Palaquium ridleyi*; Lauraceae, *Litsea grandis*; Anonaceae, *Polyalthia glauca, Xylopia fusca*; Burseraceae, *Santiria nana*; Icacinaceae, *Stemonurus capitatus*; Palmae, *Cyrtostachys lakka, Zalacca conferta*; Cyperaceae, *Mapania palustris*; Pandanaceae, *Pandanus* spp.

Discussion

The sequence of formation of lowland peat commences with the formation of a bar to give a basin in which drainage is impeded. Most peat swamps are formed by cutting off the sea from the basin so formed so that the original vegetation would consist of typical sea-coast formations which are gradually replaced by peat swamp vegetation. Evidence for this mode of formation has been obtained by palynological and C_{14} analysis of peat from Morudi peat swamp, Sarawak (Wilford, 1959) and the Lawas peat swamp, Brunei Bay. The depth of peat in the Lawas swamp was a maximum of 15 feet and peat from 10 feet was found to be 1,830 ± 120 years old.

The Morudi swamp contains peat to a depth of 35–40 feet and has an area of about 120 square miles. The age of the peat was as follows:

Depth in feet	
16	2,255 ± 60 years
33	3,850 ± 55 years
39	4,270 ± 70 years

Palynological evidence showed that at the base of the peat the clay contained abundance of Nipah (*Nipa fruticans*) and mangrove pollen (*Rhizophora someratia*) while from 28 feet upwards *Gonostylus* pollen occurs, and from 16 feet upwards *Shorea* and *Pandanus* pollens occur. The last two species are typical of the peat swamp vegetation.

The results therefore indicate that the peat has accumulated on mangrove swamp at the rate of 1 foot per 100 years for approximately the last 4,500 years. Since the coastline is at present 30 miles from the sampling area the lowlands have extended seawards at the rate of approximately 30 feet per year for 4,500 years.

The presence of peat presupposes an abundance of vegetative source material and rainfall which is usual in the equatorial tropics. However, areas adjacent to the peat swamps which are freely drained contain very little humic materials in their soil profiles. An additional special edaphic factor of water-logged conditions is therefore required, which will prevent or inhibit oxidation of the vegetable matter. Once the peat swamp is formed it may form a dome-shaped structure with its centre above the general level of the surrounding land (Polak, 1933). In addition to anaerobic, waterlogged conditions in the peat swamp, low pH is probably also required. In this respect Mohr and

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On the Malayan Peninsula a number of factors favour the development of peats. These are the continually wet climate with no marked drought season, an abundance of vegetation and the presence of acidic granite rocks over most of the Peninsula. However, peat accumulations occur only on the lowlands and the highlands and the amount of humic material in soils between these two is very low. On the highlands peat accumulates in areas where the temperatures are relatively low, while on the lowlands peat occurs under special conditions of waterlogging and where surface run-off water can accumulate from adjacent areas. In the freely drained areas on the lowlands and slopes the temperatures are high enough for all organic matter to be rapidly oxidized.

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